RESEARCH HIGHLIGHT

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UPDATE OF ROOF TRUSS DESIGNS WITH NAILING SCHEDULES

INTRODUCTION

Early in the 1960s, the development of wood roof trusses for residential construction provided interesting alternatives for contractors and designers. Using the strength of a triangle—the simplest geometric shape—designers were able to come up with space frames made of smaller, lightweight framing members, which could span greater distances and could support ceiling finishes. When wood roof trusses were first built, wood plates (gussets) and nails held the joints of the truss together. Soon, these joints became metal plates with nails and finally, stamped metal plates.

The original trusses were generally handmade, on-site, on the ground. Small framing members, usually 2 in. x 4 in. (38 mm x 89 mm) or 2 in. x 6 in. (38 mm x 140 mm) were cut and laid out in a pattern. The joints were then covered with plywood and nailed in accordance with tables provided. The two most commonly used engineering patterns in the early days of residential roof trusses were the *Fink and Howe*. The Fink has a "W" pattern and the Howe has a centre post.

GOAL OF THE STUDY

The goal of this study was to review and update the "Roof Truss Design with Nailing Schedules"(RTDWNS) section of *Canadian Wood-Frame House Construction*, produced by Canada Mortgage and Housing Corporation (CMHC). The RTDWNS was an appendix in earlier versions of the book, but removed in the latest editions after changes to the 1995 *National Building Code* (NBC). The NBC changes included a new calculation of roof snow load to include a rain load and also included removing span tables for Fink and Howe trusses.

RESEARCH PROGRAM

The research program reviewed previous truss design information under four main areas:

1. building codes
2. design and testing procedures
3. past performance
4. evaluation of parameters.

Building codes

The NBC has had many changes to the calculation of roof snow loads since the original code of 1941. The general trend has always been to use the ground snow load from available weather data and apply certain factors to calculate a roof snow load. In "Part 9" of the 1995 NBC for residential construction, these factors include a basic snow-load factor and a rain load.

The current, 1995 NBC refers to various components of the snow load as follows:

a) Ground snow load—an amount of snow measured at weather stations across Canada and determined to be a 1-in-30 year-occurrence. Based on a value of 20.9 lb/ft.^{3} (1 KN/m^3) for new snow and 41.8–104.5 lb/ft.^{3} (2–5 KN/m^3) for old snow, the ground snow load is determined for various locations across Canada. The 1995 NBC states: "Tabulated Values cannot be expected to indicate all the local differences in ground snow load. For this reason, especially in complex terrain areas, values should not be interpolated from the

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table for unlisted locations. Values at other locations can be obtained from Environment Canada."

This is a change from previous codes.

b) Roof snow load—results from surveys of snow loads on roofs indicate that average roof loads are generally less than loads on the ground. The roof snow load is therefore a percentage of the ground snow load as detailed.

c) Rain load—a contributory amount of load due to rain that collects on a roof with snow.

d) Specified snow load—this is the term used to describe the total load due to the ground snow, multiplied by various factors added to the rain load. In "Part 9" of the code, the specified snow load is simply calculated using the following equation:

$$S^{*} = C_b^{*} \times S_s^{*} + S_r^{*}$$

where S^{*} is the specified snow load;
where C_b^{*} is the basic snow-load roof factor, which is 0.5 where the entire width of a roof does not exceed 4.3 m (14 ft., 1 in.) and 0.6 for all other roofs.

Where S_s^{*} is the 1-in-30-year ground-snow load in kPa as taken from "Appendix C, Climatic Information for Building Design in Canada," of the 1995 *National Building Code.*

where S_r^{*} is the associated 1-in-30-year rain load in kPa as taken from "Appendix C, Climatic Information for Building Design in Canada," of the 1995 *National Building Code.*

Design and testing procedures

The design and testing information available for wood framed trusses with wood gusset plates dates back to the 1960s. These tests used a certain procedure for load duration, measurement and allowable deflection. This test procedure is still used today for truss testing and is recognized by the NBC and Canadian Standards Association (CSA). The criteria are basically defined as follows:

> Lumber roof trusses shall be capable of withstanding a load equal to the ceiling load plus 2 and 2/3 times the design roof snow load (but not less than 60 psf) for 24 hours. Such trusses shall not deflect more than 1/360 of the span after being loaded with the ceiling load plus 1 and 1/3 the design roof snow load (but not less than 30 psf) for 1 hour.

This standard is confirmed in "Technical Note No. 423" produced by the National Research Council in a 1964 *Technical Bulletin.* The 1995 NBC uses the same criteria for any roof trusses (Article 9.23.13.11) not designed in accordance with "Part 4." The latest standard for load test procedures for wood roof trusses for houses and small buildings is CSA S307-M1980 and this same standard is applied.

This unchanged design standard means the testing and data information from the original truss testing carried out by scientists in the 1960s, which was used until 1995, is still relevant.

Past performance

Wood-framed trusses with plywood nailed gusset plates have a good performance history. These trusses have proven satisfactory in residential home and garage construction when good construction practices and guidelines are followed. Research from various sources found that roof failures are site-specific.

Other testing reports for wood trusses with plywood gussets by other organizations, including the American Plywood Institute, found that wood truss performance was satisfactory or better than expected.

Evaluation of parameters

Each parameter of the tables was reviewed with reference to current standards where applicable:

a) **Lumber grade**—The lumber grades specified refer to the National Lumber Grades Authority Standard Grading Rules. This standard was updated in 2003. The lumber grade requirements for the tables should be changed to read:

Top and bottom chords—S-P-F No. 1

Web members—S-P-F No. 2 or No. 1

The S-P-F (Spruce-Pine-Fir) lumber designation includes the following species: White Spruce, Engelmann Spruce, Black Spruce, Red Spruce, Lodgepole Pine, Jack Pine, Alpine Fir, Balsam Fir. These species all have similar performance properties.

Gusset plate specifications—the original plywood used in the testing of the trusses was Douglas Fir Sheathing Grade 12.5 or 1/2 or 3/8 in. (9.5 mm). Each subsequent design has used 1/2 in. (12.5 mm) and this has been maintained since it simplifies the materials required. The grade designation for this plywood should read as follows:

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* It is proposed that these factors be adjusted in the 2005 NBC to reflect a more common practice worldwide of using 1-in-50-year Climatic Data. However, the overall effect on the specified snow load (S) will be minimal as C_b will be reduced accordingly. This proposed change will not affect the designs included in this report.

Plywood—DFP

Bond Type—EXTERIOR

Sheathing—SHEATHING or SHG

Standard—CSA 0121-M

b) **Nail specifications**—the charts refer to all nails being 3 in. (76 mm) common steel wire, except for the fastening of the trusses to the top of the exterior wall, which requires 31/4 in. (82 mm) nails. This specification is still adequate. Galvanized nails should be considered. Spiral nails cannot be considered due to their lower slip-resistance. The nails must still be clinched at the open end, as this provides double the shear resistance for the gusset joints.

c) **Member joint details**—this refers to the number of nails and size of gusset plates and this will not be changed from the previous tables.

d **Cantilever details**—the cantilever detail used in the tables has been brought forward from the original design testing. It will remain the same for the new tables. The use of a post strut at the outside wall for all cantilevers has proven effective and is used on many truss designs. It simply divides the truss at the bearing point into two separate trusses.

e) **Raised heel design**—again this was not altered from the original design. The raised heel will create about 9 in. (225 mm) of space at the eave. The detail is effective and is recommended to obtain higher insulation levels and better soffit venting.

f) **Eave projection**—the current standard allows eave projections up to 3 ft., 4 in. (1,016 mm) for a 2 x 4 (38 mm x 89 mm) top chord and 4 ft., 8 in. (1,422 mm) for a 2 x 6 (38 x 140 mm) top chord.

From a performance point of view this is excessive since ice and snow buildup generally occur at this location. Experience has shown that this will sag over time. The eave projection is recommended to be limited to 3 ft. (914 mm) as measured horizontally from the exterior wall outside face, but this is not mandatory.

g) **Roof slopes**—roof slopes of 4-in-12 (1 : 3) and 3-in-12 (1 : 4) were presented as before.

h) **Roof snow load**—the roof snow-load column in the charts will be updated to a "Specified Snow Load" to match other tables in the manual and bring it to current NBC standards. Reference to local building officials is recommended for calculating this load.

i) **Roof truss bracing**—web members longer than 1.82 m (6 ft.) require bracing. This bracing consists of a 1 in. x 3 in. (19 mm x 76 mm) nailed with two, 2 in. (50 mm) nails across all of the compression members for the full length of the roof.

j) **General requirements**—there are many general requirements noted on the original tables and these will be carried forward to the new tables as follows:

- To ensure maximum stiffness, the upper chords must be in good bearing contact at the peak.
- Trusses with spans below or between those listed may be used provided the nailing is not less than that shown for the larger span.
- Truss members shall not be notched, drilled or otherwise weakened for any reason.
- The trusses shall be installed in a plumb position and each end shall be toenailed to the wall with three, 31/4 in. (82 mm) common nails. The top chord must be laterally supported by sheathing or by furring strips (maximum 18 in. [450 mm] on centres for furring strips).
- The designs are not intended for use in buildings with attics accessible by stairway or where the bottom chord is subjected to concentrated loads.

IMPLICATIONS FOR THE HOUSING INDUSTRY

In Canada, because of the many remote locations and difficulties in accessing many building sites, there is a need for design details for site-built trusses. *Canadian Wood-Frame House Construction* is helpful to builders, contractors and homeowners for simple construction techniques and design information for all aspects of house construction.

The re-evaluation and updating of the information and tables for site-built trusses provides a simple design for one type of truss. Where it is difficult to obtain manufactured trusses, or where they are not readily available, this information can be used to site-build Fink-type trusses for small buildings.

CMHC Project Manager: Darrel Smith

Consultant: Oaktree Engineering Ltd.

Housing Research at CMHC

Under Part IX of the *National Housing Act*, the Government of Canada provides funds to CMHC to conduct research into the social, economic and technical aspects of housing and related fields, and to undertake the publishing and distribution of the results of this research.

This fact sheet is one of a series intended to inform you of the nature and scope of CMHC's research.

To find more *Research Highlights* plus a wide variety of information products, visit our Web site at

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or contact:

Canada Mortgage and Housing Corporation
700 Montreal Road
Ottawa, Ontario
K1A 0P7

Phone: 1 800 668-2642
Fax: 1 800 245-9274